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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Method of producing Nonageing Extra Deep Drawing Cold-Rolled Steel Sheet

We, YAWATA IRON & STEEL CO., LTD., a Japanese company of No. 1-chome, Marunouchi, Chiyoda-ku, Tokyo, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of producing low carbon cold-rolled thin steel sheet which possesses excellent deep drawability and stretchability and moreover is nonageing.

Heretofore, various methods have been applied of producing deep drawing cold-rolled steel sheet. One of these conventional methods teaches that so-called aluminium-killed steel sheet is prepared by deoxidizing molten steel produced by a conventional steel making process by means of aluminium, and said aluminium-killed steel sheet is cast to make a steel ingot, which ingot is then subjected to slabbing, hot-rolling and cold-rolling. The thus obtained steel sheet is bright-annealed for recrystallization so that any hard fibrous structure produced during the cold-rolling may be eliminated. This bright-annealing for recrystallization is followed by a refining rolling and further, if necessary, by a leveling to obtain a final product.

In producing a deep drawing steel sheet by working on an aluminium-killed steel a considerable degree of deep drawability may be obtained, provided that the production conditions are adequate, owing to the precipitation of aluminium nitride as so-called elongated grains due to difference in growing velocities of recrystal grains depending upon the direction of said precipitation of aluminium nitride, and at the same time nonageing properties may be obtained owing to the fixation of nitrogen in the steel by aluminium. However, the aluminium-killed steel is inherently defective in that the yield is low, the surface state is inferior and the cost of production is high. Consequently, the application of the aluminium-killed steel is limited to special cases and particularly recently is on the decrease.

Besides, in order to improve a deep drawability of steel investigations are being made of producing deep drawing low carbon rimmed steel by applying a method of annealing for decarburization, which has been recently developed, that is, a method in which normal low carbon rimmed steel in a molten state is first prepared and is then subjected to blooming, hot-rolling and cold-rolling in the same manner as in the case of aluminium-killed steel. Thereupon the thus treated steel is annealed in an atmosphere containing wet hydrogen to effect recrystallization and decarburization.

In this method the annealing must be, of course, carried out under the adequate conditions (particularly, annealing temperature, holding time, method of decarburization etc.). However, if the same deep drawability of the steel is intended by this method as in the case of an aluminium-killed steel, a danger must be still taken into consideration of causing rough surface, presenting so-called orange peel skin state, when subjecting said steel to press-work, because of the crystal grain becoming coarse, in most cases as coarse as those below size number 6 according to the standard classification of grain size prescribed by A.S.T.M. Moreover, in this annealing method it is to be noted that an improvement of nonageing properties may be theoretically possible if denitrogenation is carried out

together with decarburization, which is, however, practically not feasible and has never been practiced industrially. Therefore, by the annealing method of applying to an extremely low carbon rimmed steel it is not possible to obtain both deep drawing and nonageing properties, though the deep drawing properties only may be obtained as desired.

In view of these facts the inventors succeeded in providing a method of producing a cold-rolled steel sheet which possesses both extra deep drawing and nonageing properties, without using an aluminium-killed steel by carrying out the following measures: steel having a relatively high carbon content is first prepared in a steel-making furnace. After tapping from the furnace, the molten steel is subjected to a vacuum treatment, in which also denitrogenation may be performed together with decarburization and deoxidation. At the end stage of the degasification in the vacuum vessel boron is added to the molten steel. By casting said molten steel a semi-killed steel ingot is obtained. After subjecting said semi-killed steel ingot to slabbing and cold-rolling, thereby to make the ingot to a steel sheet of the predetermined thickness, the steel sheet is subjected to a special annealing for decarburization, whereby an excellent deep drawability is rendered to the steel. At the same time, by the effect of boron added to the steel, crystal grain size is regulated and nitrogen in the steel is fixed, whereby ageing may be prevented. Thus, by the method of the present invention a nonageing extra deep drawable cold-rolled steel sheet can be obtained.

The object of the present invention is to provide a method of producing nonageing cold-rolled steel sheet which is excellent in deep drawability and stretchability.

Another object of the present invention is to provide a method of producing from a semi-killed steel ingot a nonageing steel sheet which is excellent in deep drawability and stretchability.

Further objects of the present invention will be clear from the following description with reference to the attached drawings in which:—

Fig. 1 shows an example of various properties of the cold-rolled steel sheet prepared by the method of the present invention, particularly as compared with those of cold-rolled steel sheets prepared by other methods, said steel sheets being of the same thickness as the product of the present invention.

Fig. 2 shows an example of strain-ageing of the cold-rolled steel sheet prepared by the method of the present invention, in comparison with those of the cold-rolled steel sheets prepared by other methods.

In the drawings, the Lankford value, indicating the deep drawability of a thin steel sheet, is the ratio (r) of the strain in the width of sheet (Ew) to the strain in the thickness of the sheet and

$$r = \frac{Ew}{Et} = \frac{1 - \frac{W}{Wo}}{1 - \frac{Wolo}{Wl}}$$

where Wo and W are the widths of the test piece before and after a tension deformation caused by drawing the test piece up to a uniform elongation and lo and l the gauge length before and after the tension deformation, the assumption being made that the volume remains constant in a plastic deformation.

The conical cup value is that given by the Fukui test in which a test piece of specified size is placed horizontally in a conical die and is drawn to form a cup with a specified punch until the bottom of the cup is fractured. The diameter of the cup at fracture is measured and is an index of the drawing and forming qualities of the steel.

The strain-ageing index is the difference between the stress when a strain of 7% to 10% is given to a tension test piece and the stress at the same strain (which will be lower) when the test piece is subjected to a tension test after artificial ageing for 1 hour at a temperature of 100°C. If the value of the strain ageing index is within 1 kg./mm^2 the material is practically non-ageing.

A molten steel containing 0.06 to 0.12 wt. %, preferably 0.080 to 0.12 wt.% carbon and 0.03 to 0.05 wt.% oxygen is prepared in an open hearth furnace or converter. After tapping, the molten steel is subjected to a vacuum treatment, for instance, a method of degasifying in a vacuum vessel by sucking up a part of said molten steel contained in a ladle into the vacuum vessel as described in British Patent 801518 or a method of receiving a ladle in the vacuum vessel, to effect deoxidation and decarburization or, if necessary, followed by a further carburization and subsequent deoxidation, and the degasification is performed to such a degree that the degasified steel may contain 0.03 to 0.10 wt.%, preferably 0.06 to 0.10 wt.% C and below 0.020 wt.% oxygen, that is, below the content of oxygen at which boron to be subsequently added will not be oxidized. In case of need, a deoxidizing agent such as Al may be added in a small amount to regulate the degree of deoxidation. Thereupon, boron alloy, for instance, ferro boron is added in such an amount that its content may total 0.003 to 0.010 wt.%, preferably 0.004 to 0.10 wt.%. Then, the molten steel is cast to make steel ingot.

The thus produced steel ingot is a semi-killed steel because of the oxygen content being low, in which also the yield of boron is high.

Such a semi-killed steel is superior in surface state to an aluminium-killed steel. Moreover, it is possible to produce a large-sized ingot from the semi-killed steel, which makes the production cost low. Impurities in the steel may be further reduced by the vacuum degasification treatment, whereby the degree of purity may be improved. The ingot is then bloomed to make a slab of certain dimension, which is then hot-rolled after the necessary surface treatment. The hot-rolling is accomplished at a temperature above the A_3 transformation point of steel, that is, a temperature ranging from 870 to 910°C and the hot-rolled steel sheet is coiled up at a temperature of about 600°C. The hot-rolled coil is then cold-rolled at a reduction rate of 50 to 80% in thickness by a continuous or reversible cold-rolling mill after pickling. If necessary, the cold-rolled coil is further cleaned by an electric cleaning device.

Thereafter, the coil is subjected to a bright-annealing for decarburization and recrystallization while heating the same to a temperature ranging from 650 to 750°C in an atmosphere containing wet hydrogen (for instance, HNX gas (containing 0.05 vol.% CO_2, 0.05 vol.% CO and 3 to 10 vol.% H_2 and rest being N_2) of dew point of 20 to 30°C) by using an annealing device prepared for our invention, for instance, the open coil annealing device as described in British Patent 878497, whereby the carbon content in the steel is finally reduced to below 0.005 wt.%. Then, the annealed steel is rolled for refining at a reduction rate of 0.5 to 1.5% in thickness according to the normal operation to make the product of the final gauge. The said rolling for refining is to be carried out to prevent stretcher strain from occurring in regulating the surface and shape of the steel sheet and in press-working the same.

The chemical composition of the product prepared by the present invention comprises below 0.005 wt.%, preferably below 0.003 wt.% C, and 0.003 to 0.010 wt.%, preferably 0.006 wt.% boron, the rest of the components being in a range of normal low carbon steel, respectively. The crystal grain size corresponds to the size number 7.5 to 8.5 of A.S.T.M., being regulated by the boron content in the steel. As to the mechanical properties, though largely influenced by the annealing conditions, particularly annealing time and decarburizing treatment, the product of this invention is somewhat soft and is much superior in the total elongation and Erichsen value to an aluminium-killed steel. Particularly, it has a large Lankford value (average Lankford value of three directions of 0°, 45° and 90° to the rolling direction), which is said to be one of the best criteria for judging press-shapability of cold-rolled thin steel sheet, and is superior in the conical cup value to an aluminium-killed steel of the same thickness. For instance, one example of the conical cup value of the steel sheet of 0.8mm thick prepared by the method of the present invention shows 37.05, while that of an aluminium-killed steel of the same thickness is 37.2 to 37.4. These tests show that the product of the present invention is excellent in deep drawability and stretchability. Further, as a result of the decarburization and the fixation of nitrogen contained in the steel by means of boron the strain-ageing index is below 1.0 kg/mm², and nonageing properties of the same level as of an aluminium-killed steel may be maintained. The diminution of impurities contained in the steel and the improvement of the degree of purity as a result of the vacuum degasification treatment free the product of the present invention from the danger of producing rough surface or other faults in the press work. As compared with an aluminium-killed steel the product of the present invention has further advantages such as better yield, superior surface state and lower production cost.

As to the vacuum degasification, mention has been made in the foregoing mainly of the method disclosed in British Patent 801518. However, it is not limited to that. For instance, the method of vacuum degasification of British Patent 920874 may also be applied.

Example:

A molten steel comprising 0.10 wt.% C, 0.04 wt.% O, and Si, Mn, P and S in amounts usually contained in a normal steel respectively, was prepared in an open hearth furnace according to a conventional process and was tapped therefrom.

Said molten steel was received into a ladle and then subjected to a vacuum degasification, in which a part of said molten steel was repeatedly sucked up in the vacuum vessel to degasify the same. At the final period of the degasification FeB was added to the molten steel to obtain a steel ingot of the following composition after casting:

C	Si	Mn	P	S	B	Fe
0.080	0.010	0.30	0.010	0.013	0.006	balance (wt.%)

Said steel ingot was slabbed, and then the obtained slab was hot-rolled to make sheet at a finishing temperature of 880°C, which was coiled at 625°C. After pickling, said hot-rolled sheet was then cold-rolled at a reduction rate of 72% in thickness to obtain a cold-rolled sheet of 0.8mm thick. The thus obtained cold-rolled steel sheet was subjected to an annealing as disclosed in British Patent 878497 at a temperature of 740°C by using HNX gas. The carbon content after the annealing was 0.003 wt.%. Finally, the an-

nealed sheet was rolled at a reduction rate of 1.0% in thickness for refining.

The characteristics of the steel produced by the present invention are exemplified in Figs. 1 and 2 and Table. Rimmed cold-rolled steel sheet, rimmed decarburized steel sheet and aluminium-killed steel sheet are cited for the purpose of comparison.

TABLE

Chemical Compositions in Weight %

	C	Mn	P	S	B	Fe
Semi-killed cold-rolled steel sheet of the present invention	0.003	0.30	0.010	0.013	0.006	balance
Rimmed cold-rolled steel sheet	0.085	0.33	0.017	0.017	—	balance
Aluminium-killed cold-rolled steel sheet	0.042	0.30	0.012	0.016	—	balance
Rimmed decarburized cold-rolled steel sheet	0.003	0.33	0.017	0.017	—	balance

The thickness of each steel sheet is 0.8 mm., respectively.

As evidently seen from Fig. 1, the cold-rolled steel sheet obtained according to the method of the present invention shows a superiority in the deep drawability to any cold-rolled steel sheet of the conventional methods, showing the Erichsen value of 11.5mm and the conical cup value of less than 37.0mm. The cold-rolled steel sheet of the present invention is also superior to the conventional cold-rolled steel sheets in the strain-ageing properties as indicated in Fig. 2, because its index of the steel sheet of the present invention shows 1 kg/mm^2 or below it.

WHAT WE CLAIM IS:—

1. Process of producing nonageing extra deep drawing cold-rolled thin steel sheet comprising the steps of tapping from a steel making furnace a molten carbon steel said molten steel having a carbon content ranging from 0.06 to 0.12 wt.%, producing a low carbon semi-killed steel ingot by subjecting said molten steel tapped from the furnace to a vacuum-degasificating treatment to regulate a degree of deoxidation so that carbon content and oxygen content in the vacuum degasified molten steel may be between 0.06 to 0.10 wt.% and below 0.02 wt.%, respectively, thereupon by adding boron to the thus vacuum-treated molten steel so that said molten steel may contain boron in a total amount of 0.003 to 0.010 wt.%, hot-rolling the thus obtained steel ingot and thereafter cold-rolling the hot-rolled steel sheet at a reduction rate of 50 to 80% in thickness, subjecting the cold-rolled steel sheet to a bright-annealing for decarburization and for recrystallization at a temperature of 650 to 750°C in an atmosphere containing wet hydrogen to make the carbon content to below 0.005 wt.% and cold-rolling for refining the thus obtained steel sheet at a reduction rate of 0.5 to 1.5% in thickness.

2. Process of producing nonageing extra deep drawing cold rolled thin steel sheet according to Claim 1 and substantially as described.

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This drawing is a reproduction of the Original on a reduced scale.

FIG. 1

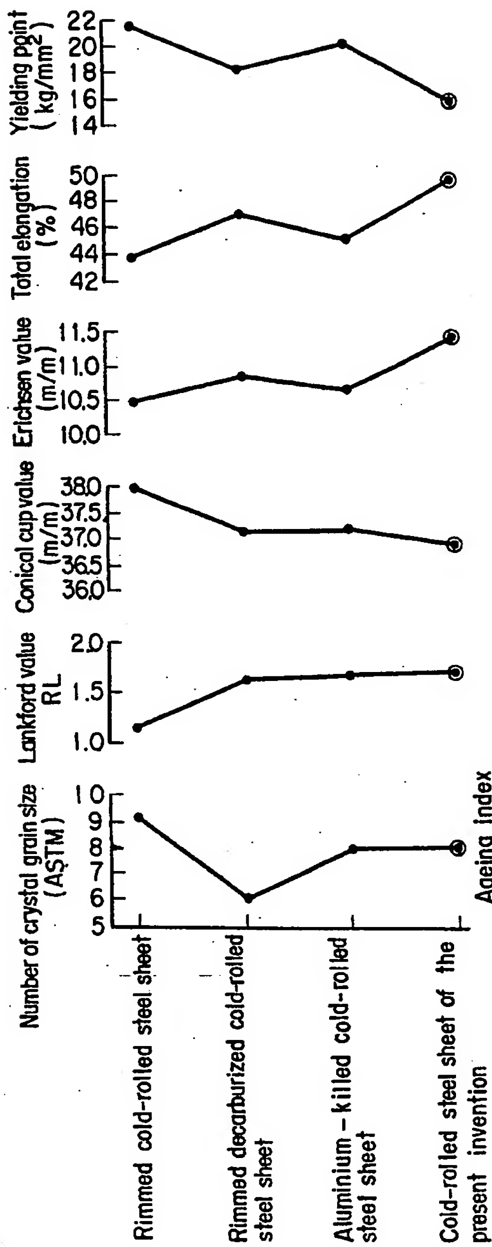

FIG. 2